TELEROBOTICS

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This presentation summarizes NASA's future plans and current technology programs for telerobotics. Telerobotics involves electromechanical systems which have manipulation or mobility capability and are controlled by an operator. If the operator provides direct control through manipulation of master-slave servomechanisms and provides all the control intelligence, the system is referred to as teleoperated. If the operator provides only goals for an otherwise completely autonomous system, the system is a robot. In the fairly near term systems will be somewhere in between, will combine teleoperated and autonomous modes, and are therefore called telerobots.

Telerobots will be used for assembly and servicing in earth orbit and will operate from the space shuttle, the space station or, eventually, in high orbits from an orbit transfer vehicle (OTV). These telerobots will initially be attached to a host vehicle, such as the shuttle, but will be able to free-fly by the year 2000. These earth orbiting telerobots are likely to be somewhat anthropomorphic, at least initially, including two arms with dextrous end effectors, vision and force/torque sensing, and some level of artificial intelligence. Their primary mode will be to perform tasks designed for space-suited astronauts. Other telerobotic manipulators will have large crane-like arms (such as the shuttle remote manipulator system) for manuevering massive objects or supporting dextrous telerobots.

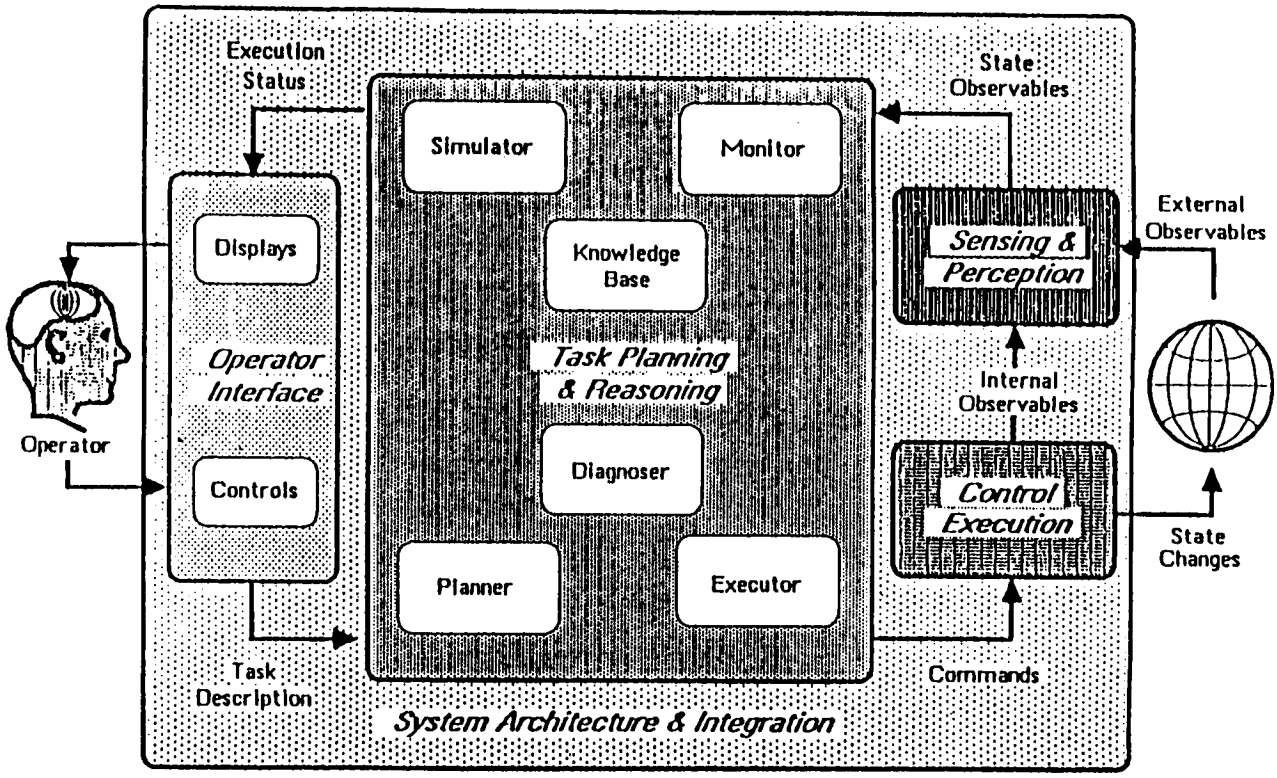
Telerobots will be used in planetary exploration to rove over planetary surfaces, initially most likely on Mars. These rovers may roll, fly or walk. They will collect and analyze geological samples and return the samples to a launch vehicle for return to earth orbit. They may be operated from earth by means of predetermined paths and thus travel slowly, or they may be intelligent enough to determine their own paths to interesting places and travel there while avoiding obstacles.

NASA OAST's telerobotic technology development is currently being integrated by the Jet Propulsion Laboratory in a series of demonstrations focused on multi-armed telerobots for dextrous manipulation. The demonstrations integrate technologies in operator interface (displays and

controls), sensing systems (vision and force/torque), task planning and reasoning (including artificial intelligence), control execution (mechanization and control of multiple manipulators and dextrous end effectors), and system architecture and integration (including executive and run-time control systems which integrate the control of the other elements). Issues of flight-qualified computers for telerobots are beginning to be investigated, and OAST is funding a modest program in flight symbolic and general purpose processors.

The military's current active involvement in telerobotics is primarily focussed on ground applications (e.g. DARPA's autonomous land vehicle program). However, joint planning efforts which include space telerobotics are being initiated with NASA in response to the president's directives for investigation of a new generation of launch vehicles and the space defense initiative.

Architecture for an Automated System



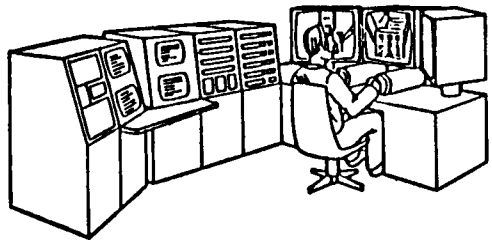
SPACE TELEROBOTICS

1987 DEMONSTRATION

STATIONARY ROBOT, SIMPLE SPACECRAFT SERVICING TASKS, SUPERVISORY CONTROL

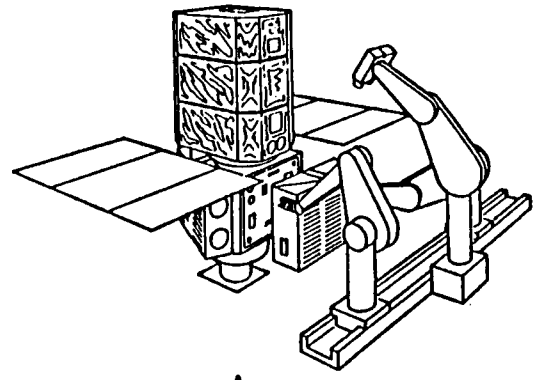
TECHNICAL ADVANCES

- SPACE SERVICING PRODUCTIVITY IMPROVEMENT
- DUAL-ARM COOPERATION
- MANUAL/POWER TOOL HANDLING



CONTROL STATION

- STEREO DISPLAYS
- TWO-ARM BILATERAL FORCE - POSITION CONTROL
- VOICE RECOGNITION/SYNTHESIS
- INTERACTIVE TASK PERCEPTION
- OFF-LINE INTERACTIVE PLANNING



RUN TIME CONTROL/PERCEPTION SYSTEM

- AUTOMATIC STEREO TASK FRAME ACQUISITION AND TRACKING
- AUTOMATED SYSTEM CONTROL AND SEQUENCING
- AUTONOMOUS/INTERACTIVE TASK EXECUTION AND MONITORING
- TELEOPERATOR CONTROL AS REQUIRED

NASA SPACE TELEROBOT LABORATORY DEMONSTRATION SEQUENCE

(ROBOT INTELLIGENCE, AUTONOMY AND TASK COMPLEXITY INCREASE OVER TIME)

- 1987 - STATIONARY ROBOT, SIMPLE SPACECRAFT SERVICING TASKS, SUPERVISORY CONTROL

  STATIONARY TWO-ARM TELEROBOT PERFORMS KNOWN SIMPLE TASKS ON COOPERATIVE SPACECRAFT USING HAND AND POWER TOOLS. LIMITED AUTONOMY

- 1990 - MOBILE ROBOT, SPACECRAFT SERVICING/RETRIEVAL, EXECUTIVE CONTROL

  MOBILE MULTIARM ROBOT PERFORMS KNOWN SIMPLE TASKS ON COOPERATIVE SPACECRAFT. LIMBER ARM INTERACTIVELY ACQUIRES AND DESPINS SPACECRAFT

- 1993 - SPACE SERVICING AND ASSEMBLY

  MOBILE MULTIARM ROBOT PERFORMS MODERATELY COMPLEX SERVICING AND ASSEMBLY TASKS INVOLVING MULTIPLE ELEMENTS

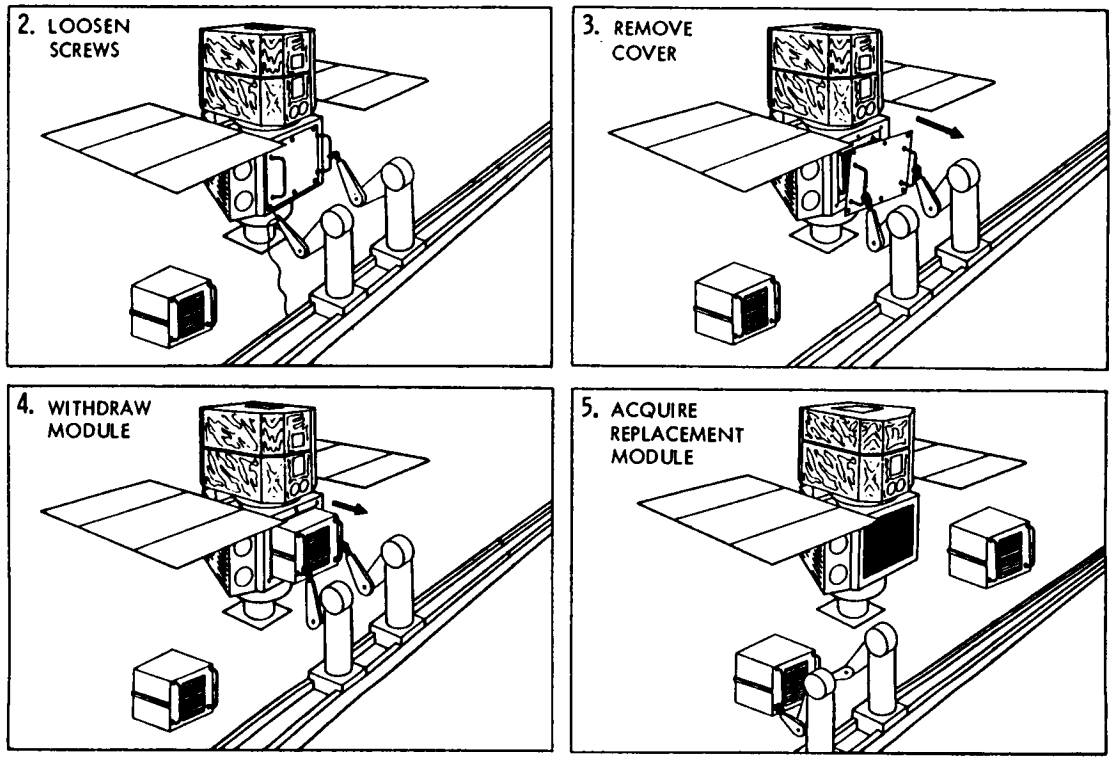
- 1996 - UNPLANNED REPAIR REQUIRING FABRICATION

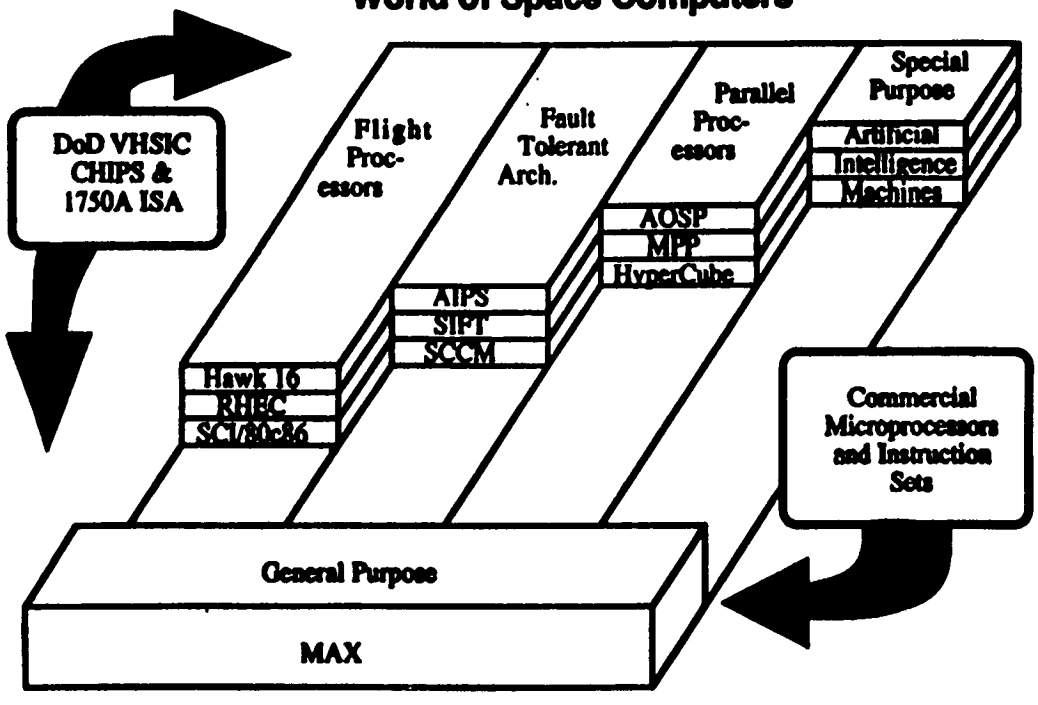
  MOBILE, MULTIARM ROBOT INSPECTS, TESTS, AND REPAIRS DAMAGED STRUCTURAL AND MECHANICAL ELEMENTS. TASK INVOLVES DISASSEMBLY, CUTTING, AND MINOR FABRICATION

- 2000 - COOPERATIVE ROBOTS, COMPLEX GOAL DRIVEN TASKS

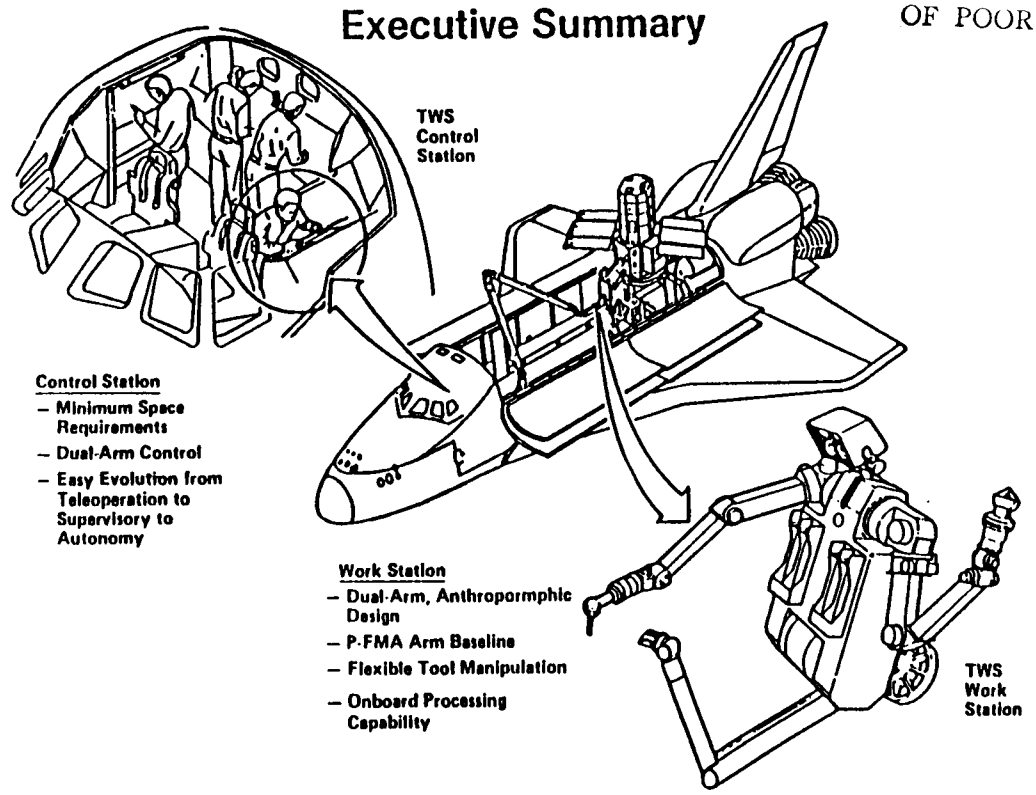
  COOPERATING MOBILE TELEROBOTS PERFORM COMPLEX TEMPORARY AND PERMANENT REPAIRS OF DAMAGED ELEMENTS USING AUXILIARY SUPPORTS, GUIDES, AND POWER TOOLS. PERIODS OF AUTONOMY MEASURED IN MINUTES

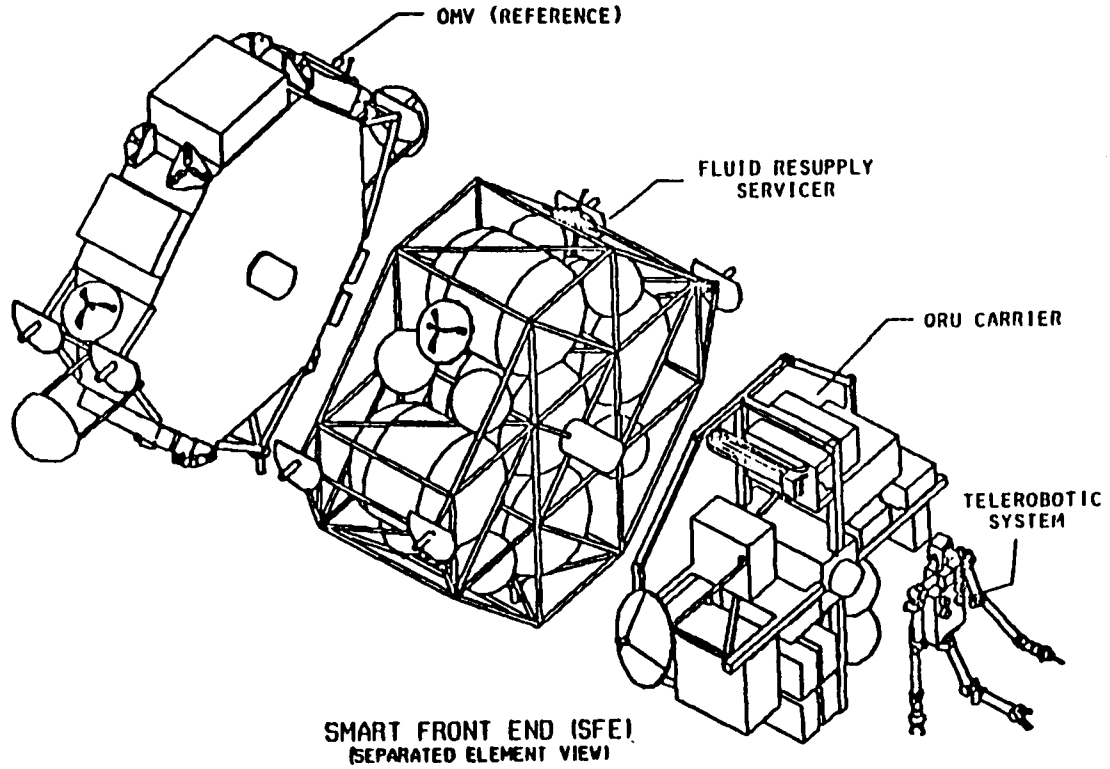
PROTOTASK EXECUTION SEQUENCE - MODULE CHANGEOUT





Executive Summary





SMART FRONT END (SFE)
(SEPARATED ELEMENT VIEW)